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I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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Dated 28 February 2003

The Patent Office

INVESTOR IN PEOPLE

23-01-03

GB0203997.2

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of:-

PS Comtek Ltd
73 Brayworth Drive
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United Kingdom
Incorporated in the United Kingdom

ADP Number: 08553018001

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

21FEB02 E697596-1 C82366
P01/7700 0.00-0203997.2

THE PATENT OFFICE
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Request for grant of a patent

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1. Your reference

2. Patent application number
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   0203997.2

   20 FEB 2003 23.01.03

3. ... postcode of the or of ... *(underline all surnames)*

   Dr Neil Alexander Keron

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   Bedford MK40 1EQ

   SECTION 30 (1977 ACT) APPLICATION FILED

   Patents ADP number *(if you know it)*

   7790157001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

   Floating Semi-Submersible Oil Production and Storage Arrangement

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   AA THORNTON & CO,
   235 HIGH HOLBORN,
   LONDON,
   WC1V 7LE.

   PF51/77
   23/1/03.

   Patents ADP number *(if you know it)*

   75001.

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
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   b) there is an inventor who is not named as an applicant, or
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Description	5
Claim *(s)*	2
Abstract	1 only
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Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Neil Keron Neil Keron

Date 20 Feb 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Neil Keron 01234 271 500

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DUPLICATE

Floating Semi-Submersible Oil Production and Storage Arrangement

The oil industry frequently makes use of floating production and storage systems for developing small oil fields. These generally use a converted crude oil tanker moored to a purpose built mooring buoy. To minimise the wave, current and wind forces on the tanker, the mooring is designed to allow the vessel to weathervane around the buoy under the influence of the resultant environmental force. Processing equipment is mounted on the deck of the vessel.

Oil production from the reervoir is via one or more subsea wellheads, through a flexible flowline from each wellhead to the mooring buoy and from the buoy to the vessel. The system also incorporates lines to carry gas and/or water from the vessel to the wellheads. Also incorporated are hydraulic and electrical lines from the vessel to allow control of the subsea wellheads. Since the vessel must be free to rotate around the buoy, the numerous fluid flow paths through the buoy result in the need for a complicated and expensive device known as a swivel. This is a precision engineered piece of equipment subject to high pressure, high temperature corrosive fluids from the reservoir and hence must be manufactured faultlessly if high maintenance costs are to be avoided.

A further disadvantage of floating production systems that employ converted tankers is that they are highly susceptible to pitching, rolling and heaving. Since the separation of the oil, water and gas which comprise the fluid stream from the reservoir is effected by means of gravity separation in large pressure vessels, the sloshing of the liquids caused by the ships motion can cause serious inefficiencies in the separation process.

An alternative type of floating production system which eliminates these problems is use of a semi-submersible vessel. Semi-submersibles have been used in the offshore industry for number of years as mobile drilling vessels, crane barges, pipe laying barges and dedicated floating production vessels. As shown in Figure 1, a semi-submersible vessel comprises a deck 1 supported above the water-line (OWL) on a number of columns 30 . The columns extend from the deck to (typically) two flotation pontoons 31 located some distance below the water-line. The advantages of a semi-submersible over a ship-shaped vessel are two-fold. Firstly, the area exposed to the waves at the water-line is less for a semi-submersible than for a ship-shaped vessel and hence the horizontal wave forces are much reduced. Secondly, because the pontoons which provide the buoyancy are much further below the water-

line than the underside of a ship, the vertical wave forces are much less. (This is because the effects of a wave rapidly decrease as one moves deeper into the water.)

The results of these advantages are that semi-submersible production vessels can be moored in the ocean without the need to provide weather vaning and that the sloshing of liquids on the deck is reduced.

Semi-submersible floating production systems (SSFPS) however have two disadvantages. Firstly, there is no significant capability for storage of the produced oil. This means that they can only be utilised where a pipeline is provided to carry the produced oil to an onshore storage/processing facility or where a dedicated moored tanker ship is provided adjacent to the SSFPS.

The second disadvantage is that the amount of processing equipment which can be fitted on deck is limited because the centre of gravity of the SSFPS is raised as weight is added to the deck. This reduces the resistance to overturning of the vessel. This resistance to overturning is quantified in a property of the vessel known as the metacentric height (usually designated GM). A high GM means a high resistance to overturning and vice versa.

A number of small oil fields have been developed using a SSFPS which have used a converted secondhand semi-submersible drilling vessel. Where the produced oil is viscous and needs large pressure vessels for separation or where gas injection or water injection equipment is required, new larger semi-submersibles are required to accomodate the equipment.

A number of attempts have been made to provide oil storage in a semi-submersible (British Patent Applications GB 2216849, GB 2207892, GB 2188291). However these allow storage of only a relatively small quantity of oil. These systems still require a dedicated moored tanker to store a marketable quantity of oil.

According to the present invention there is provided an arrangement for the storage of oil at a semi-submersible floating production vessel comprising a deck structure which is carried by means of a plurality of columns and pontoons characterized in that a reinforced concrete tank is attached below the pontoons, said concrete tank being subdivided into a plurality of chambers for storage of oil.

The present invention preferably provides a semi-submersible, floating production, storage and offloading system for the development of offshore oil and gas fields comprising a converted semi-submersible drilling vessel, a segmented, reinforced or

reinforced and pre-stressed concrete tank attached to the base of the drilling vessel, means for utilising the drilling vessels's ballast pumps to pump seawater into or out ~~of the bottom of each concrete~~ tank segment, means of directing ~~produced oil into or~~ out of the top of each tank segment.

A specific embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 shows a typical semi-submersible floating production system;

Figure 2 shows in perspective a semi-submersible drilling rig with a concrete tank attached in accordance with the present invention;

Figure 3 shows a sectional elevation of the drilling rig of Figure 2;

Figure 4 is a schematic diagram of the layout of the connection between the chambers of the concrete tank of Figures 2 and 3;

Figures 5 and 6 are further schematic diagrams showing how the chambers are connected; and

Figure 7 shows additional detail of the drilling rig of Figures 2 and 3.

Referring first to figure 2, the drilling rig 1 has a concrete tank 2 attached below columns 30 and the pontoons 31.

As shown in Figure 3, the concrete tank is segmented by internal concrete walls 3. Also shown for one chamber are the water inlet/outlet pipe 4 and the oil inlet/outlet pipe 5. The water pipe terminates in a diffuser pipe 6 close to the bottom of the chamber which minimises mixing of the oil and water as water is pumped in. The oil pipe terminates at the inner face of the upper surface to avoid the possibility of build-up of a gas pocket. Ideally the top surface of each chamber is domed slightly with the oil pipe entry at the vertex.

The tank is shown in Figure 3 with some chambers full of oil 7, some full of water 8, and some partly water and partly oil filled. The mass of the tank is such that when completely full of oil the total mass of the tank and contents is slightly greater than the mass of seawater displaced by the tank.

By constructing the base of the tank of a material of greater density than the roof, the centre of gravity of the tank and contents is slightly below the centre of buoyancy of the tank. This increase the metacentric height of the vessel allowing an increased payload to be added to the deck of the semi-submersible.

In order to maintain a constant draught during filling of the tank with oil, 1/5 of the chambers do not operate on the oil-on-water principle. These 1/5 of the chambers operate on a dry or gas-over oil principle. Prior to introduction of oil to the tank, 4/5 of the chambers are seawater filled and 1/5 are filled with low pressure natural gas. As oil is introduced to the tank 1/5 of the incoming oil is directed to a gas filled chamber and 4/5 is directed to the water filled chambers. Since oil is approximately 4/5 of the density of seawater, this arrangement ensures that the masss of oil entering the tank equals the mass of seawater being displaced to the ocean. A similar procedure is adopted in reverse when discharging oil to an adjacent tanker.

The volume of the tank is sufficiently large such that when the tank is empty, the upper surface of the tank is a considerable distance above the water-line. This allows access to the piping above the upper tank surface, to the manholes in the tank for internal inspections, to the tank-to-semi-submersible connections and to all external parts of the semi-submersible. This allows the inspections required by classification societies to be carried out without the vessel needing to go to dry dock. The only parts of the vessel not inspectable in the dry are the underside and lower walls of the tank. Since reinforced concrete is highly durable and corrosion resistant in the marine environment, a visual inspection by divers or remote underwater vehicle will be sufficient inspection for these parts.

Free liquid surfaces inside a vessel add greatly to its instability because the liquid sloshes from side to side as the vessel rolls. Two different methods are employed to minimise the free surface within the tank. The subdivided chambers are connected as shown in Figure 5 and Figure 6. In the chambers H1- N4 oil is stored above a bed of water (Figure 5). As oil is pumped in at the top of the chamber, water is displaced from the bottom. There is thus never a free surface in any of these chambers. In chambers A-G, a gas over oil filling method is employed. To minimise the free surface in chambers A-G and minimise the necessary piping and valves, these chambers are fitted with a piping system as shown in Figure 6. Oil enters chamber A through pipe 9. When chamber A is filled it overflows through pipe 10 into chamber B. Gas is displaced from the chambers via pipe 11. When the oil is to be offloaded, oil is displaced from the chambers by supplying pressurized gas to pipe 11. This arrangement ensures that only one chamber at a time can have a free surface but no valves are required outside the semi-submersible hull.

Concrete as a structural material behaves best when loaded in compression. Tensile forces must be resisted by reinforcing steel embedded in the concrete. The required quantity of reinforcing steel can be minimised by maintaining the external pressure on the tank greater than the internal pressure. To achieve this the water outlet line from each chamber is connected to a breaktank 12 located inside a column of the semi-submersible as shown in Figure 7. This breaktank is located below the elevation of the operating water level (OWL). The breaktank is vented to atmosphere 13 and the water level in the breaktank is maintained by level switches 14 and 15 acting on the semi-submersible's seawater ballast pump 16 and control valve 17 to add or remove water as necessary. To ensure that the oil system cannot overpressure the tank, the oil inlet/outlet is vented to atmosphere at a safe location 18.

Large centrifugal pumps 19 are required to offload the stored oil into shuttle tankers. Such pumps require a nett positive pressure head on their suction side (NPSH) in order to function efficiently. Normally this is achieved by locating the pumps at a lower elevation than the bottom of the storage tank. The arrangement of the present invention allows the pumps to be located above the tank inside the semi-submersible columns or pontoons where they are easily maitained, but still to be provided with a nett positive suction head. Also shown in Figure 7 are an oil export meter 20, a ballast water cleanup device 21, an oil in water alarm 22 and a gas/oil/water separator 23.

The invention is also characterized by the fact that all necessary valving, pumps and instrumentation can be located inside the columns of the semi-submersible where they are in a dry, benign environment and can be easily accessed for maintenance.

To allow maintenance , cleaning and inspection of the insides of the chambers a covered manhole 24 is provided in the upper surface of each chamber. This manhole can be accessed dry whenever the tank is fully deballasted and the upper surface is above the water line.

The invention requires no pipes or fittings protruding from the bottom of the tank. This allows easy construction onshore, skidding of the tank into the ocean, setting the tank on a suitable seabed and fitting of the semi-submersible by floating over the top of the tank and ballasting down. The tensile connections between tank and semi-submersible are then made in the dry by deballasting the tank and lifting the entire semi-submersible above the water line.

CLAIMS

1 An arrangement for the storage of oil at a semi-submersible floating production vessel comprising a deck structure which is carried by at least two underwater pontoons by means of a plurality of columns characterized in that a reinforced concrete tank is attached below the pontoons, said concrete tank being subdivided into a plurality of chambers for storage of oil.

2 An arrangement as claimed in claim 1, wherein the mass of the tank and its contents is maintained, by means of internal bulkheads and associated piping systems, such that the total mass of the tank and contents is always slightly greater than the masss of seawater displaced by the tank regardless of the quantity of oil stored in the tank at any time.

3 An arrangement as claimed in claims 1 and 2, wherein the tank is constructed of varying density materials such that the centre of gravity of the tank and contents is always lower than the centre of buoyancy causing an increase in the metacentric height of the vessel.

4 An arrangement as claimed in claims 1,2 and 3, wherein the displacement of the tank is sufficient when the tank is empty or partially empty to raise the tank and semi-submersible to an elevation where the upper surface of the tank is some distance above the waterline.

5 An arrangement as claimed in claims 1 to 4, wherein the area of free liquid surface is minimised by means of internal bulkheads and associated piping systems.

6 An arrangement as claimed in claims 1 to 5, wherein the internal pressure in the tank is maintained lower than the external pressure by means of an atmospherically vented breaktank located inside the semi-submersible vessel at an elevation below the operating water level.

7 An arrangement as claimed in claim 6, wherein the said break tank is maintained partially full by level controllers activating the semi-submersible's existing seawater ballast pumps to remove water and activating a control valve to allow addition of seawater from the ocean.

8 An arrangement as claimed in claims 1 to 7, wherein a pump is provided to discharge stored oil to a tanker and said pump is located inside a column of the semi-

submersible above the tank elevation but is provided with the necessary nett positive suction head.

9 An arrangement as claimed in claims 1 to 8, wherein all valving, pumps and instrumentation for control of the fluids into and out of the tank are located inside the columns of the semi-submersible.

10 An arrangement as claimed in claims 1 to 9, wherein covered manholes are provided in the upper surface of each chamber.

11 An arrangement as claimed in claims 1 to 10, having an abscence of piping penetrating the lower surface of the tank.

12 An arrangement as claimed in claims 1 to 11, fabricated from non-corrosive material.

13 An arrangement as claimed in any preceding claim, wherein the concrete tank is of reinforced and prestressed concrete.

14 An arrangement substantially as hereinbefore described with reference to the accompanying drawings.

DUPLICATE.

FLOATING SEMI-SUBMERSIBLE OIL PRODUCTION AND STORAGE ARRANGEMENT

ABSTRACT

An arrangement for the storage of marketable quantities of crude oil at a semi-submersible floating production vessel. The storage is achieved by hanging a segmented reinforced concrete tank to the underside of the semi-submersible vessel. By maintaining the mass of the tank and contents slightly greater than the displacement of the tank and by arranging the centre of gravity of the tank below its centre of buoyancy, the metacentric height of the semi-submersible vessel is improved. The storage arrangement for the oil provides the necessary maintenance of mass by storing 4/5 of the oil in oil-over-water chambers and 1/5 in gas-over-oil chambers. The piping arrangements minimise the free surface of liquids in the tank. The design ensures the internal pressure in the tank is less than the external pressure which minimises required reinforcement. The design provides a nett positive suction head to an oil export pump located above the storage tank inside the hull of the semi-submersible vessel. The design allows all pumps, valves and instrumentation necessary for handling stored oil within the hull of the semi-submersible where they can be easily maintained.

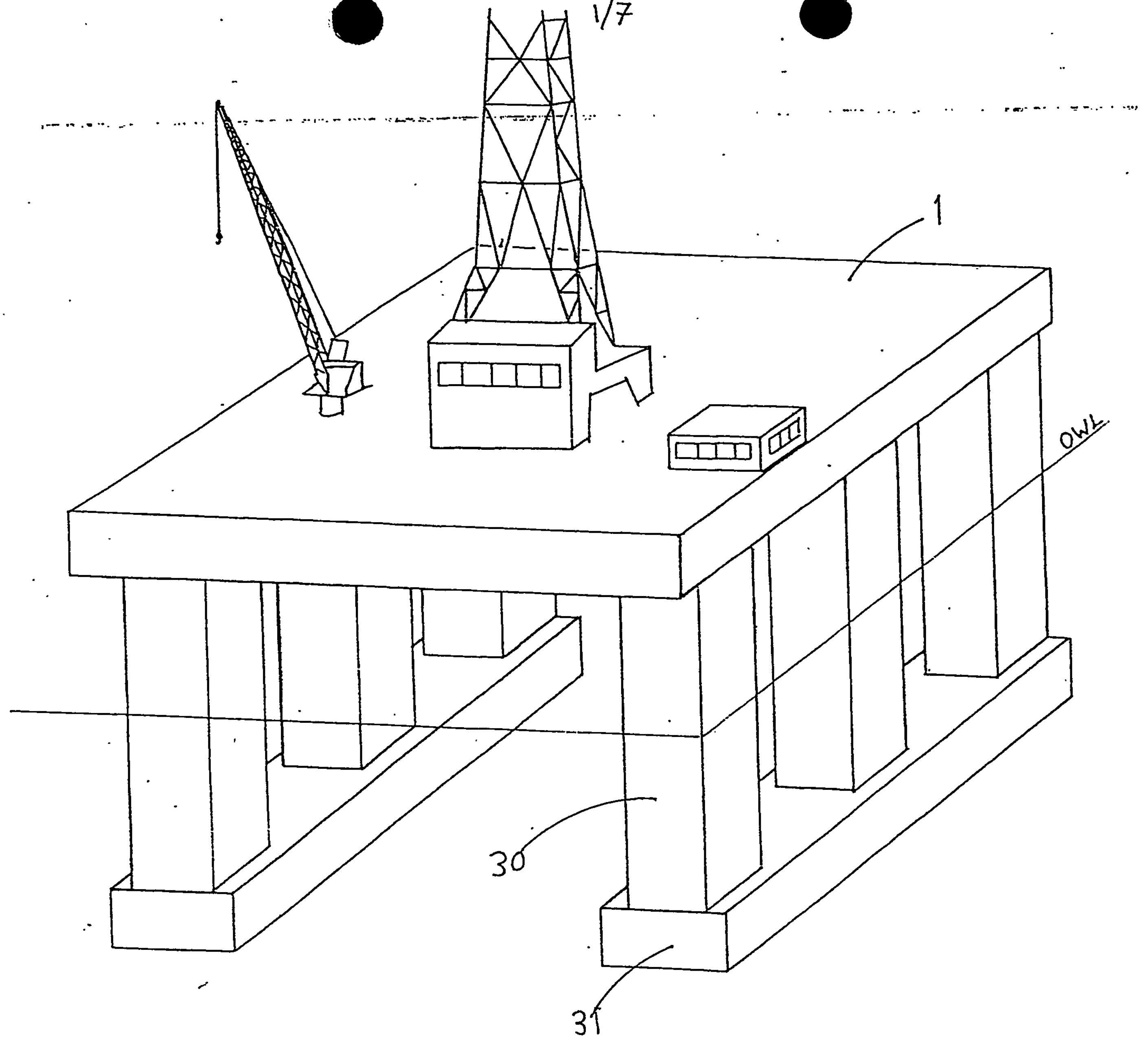


Fig 1

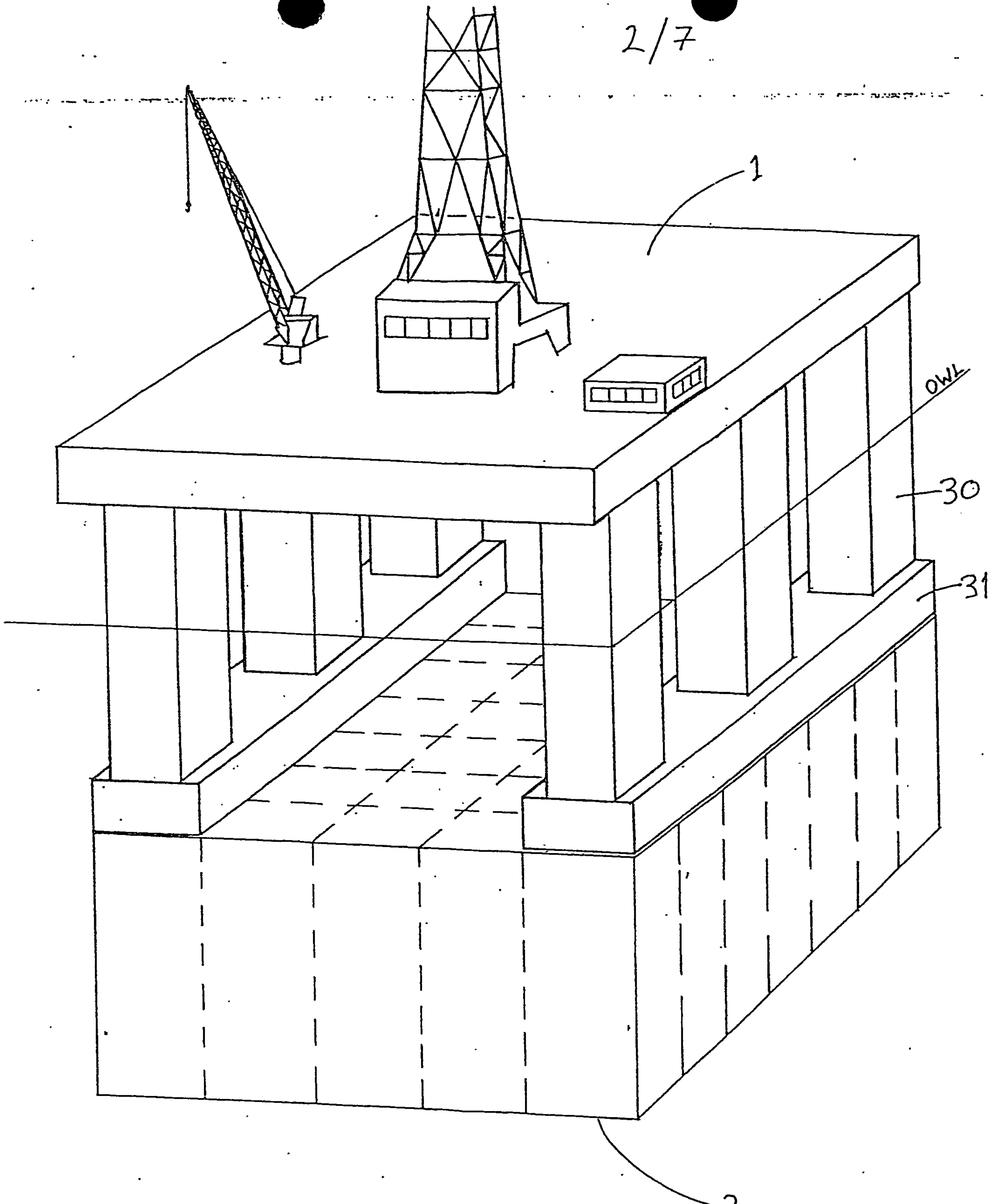


Fig 2

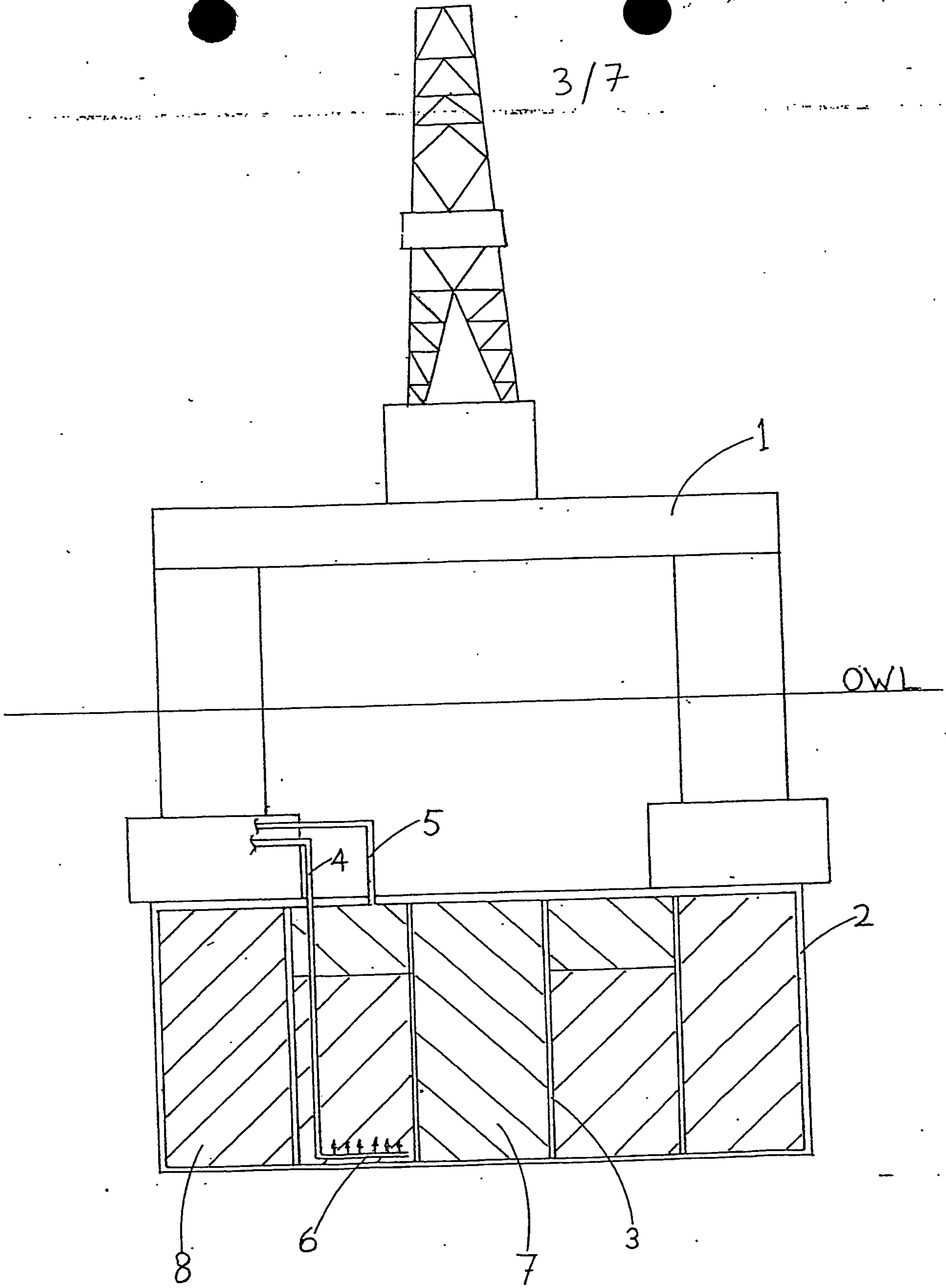
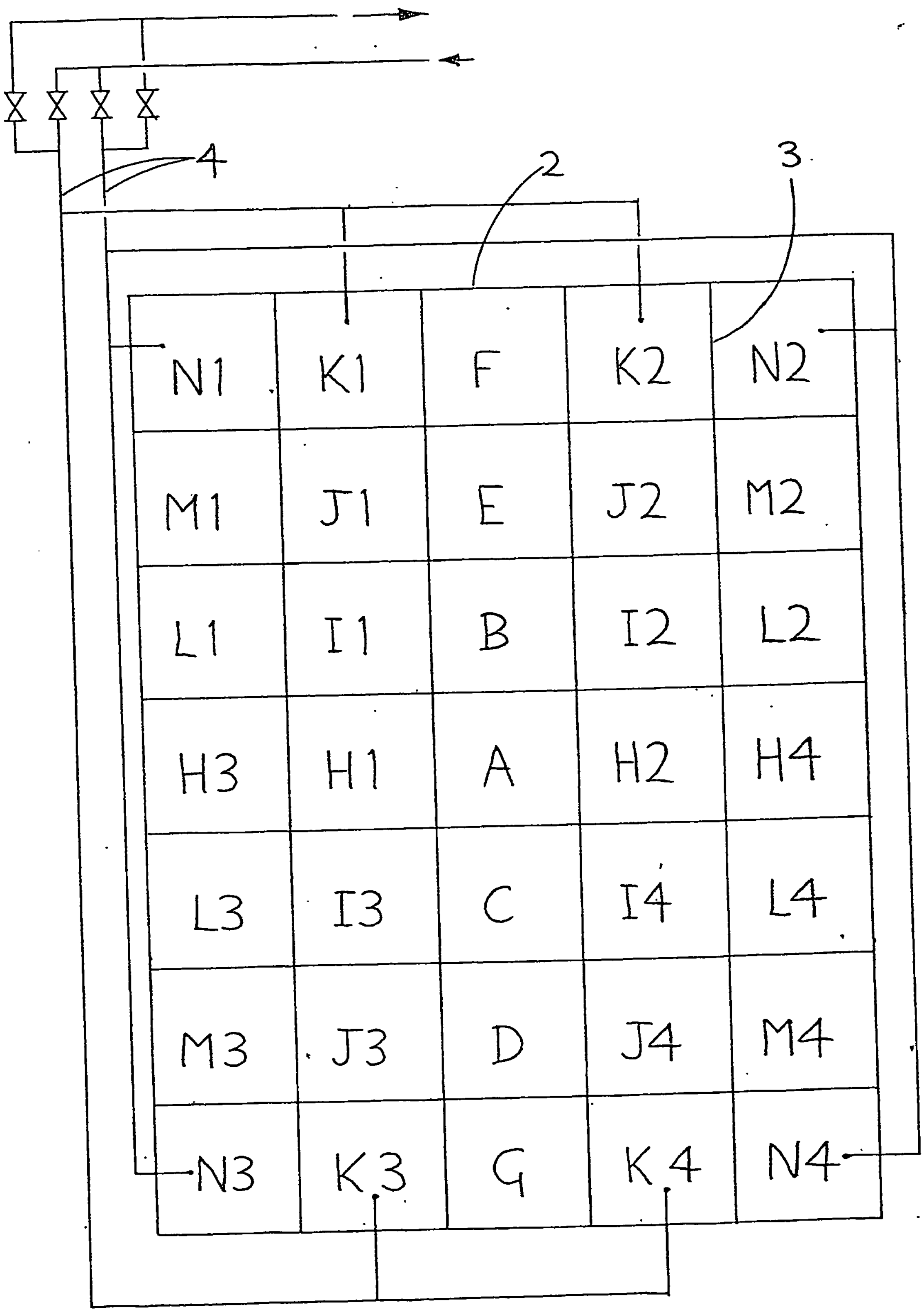


Fig 3



4
2
3
N1 K1 F K2 N2
M1 J1 E J2 M2
L1 I1 B I2 L2
H3 H1 A H2 H4
L3 I3 C I4 L4
M3 J3 D J4 M4
N3 K3 G K4 N4

Fig 4

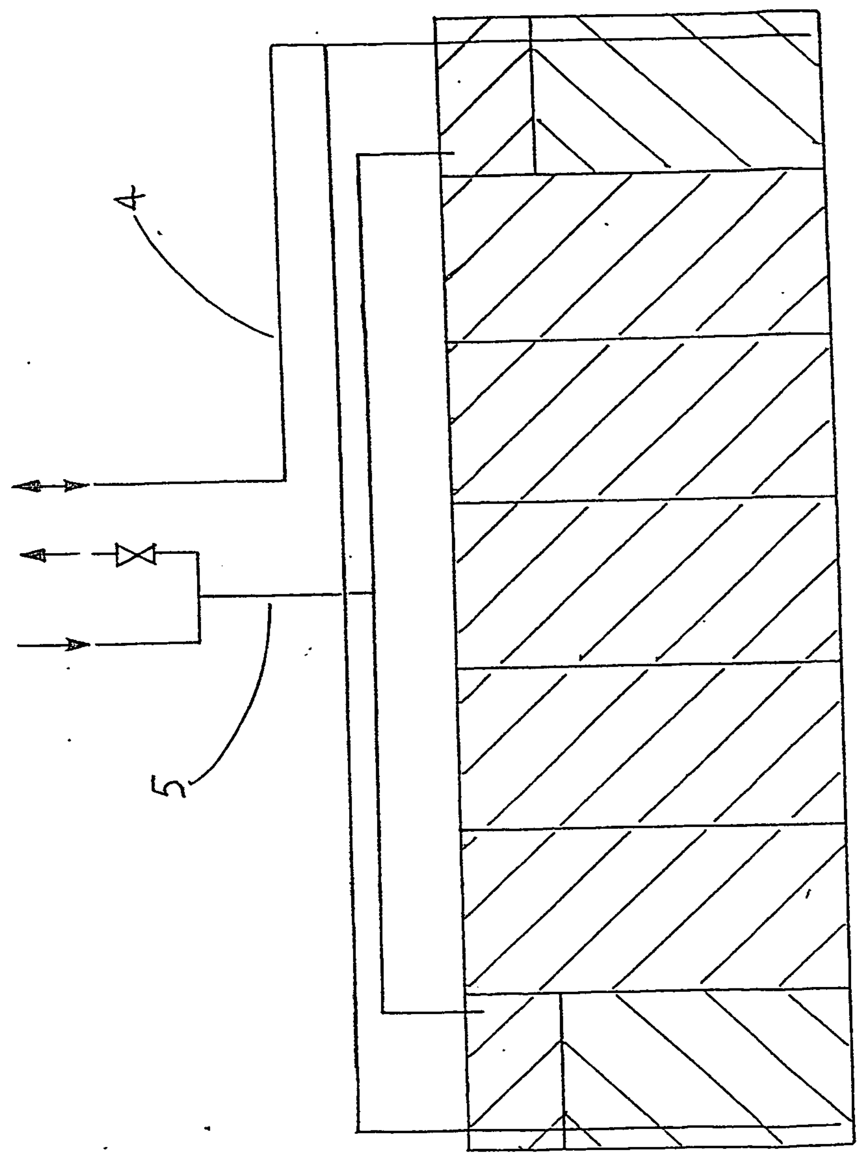


Fig 5

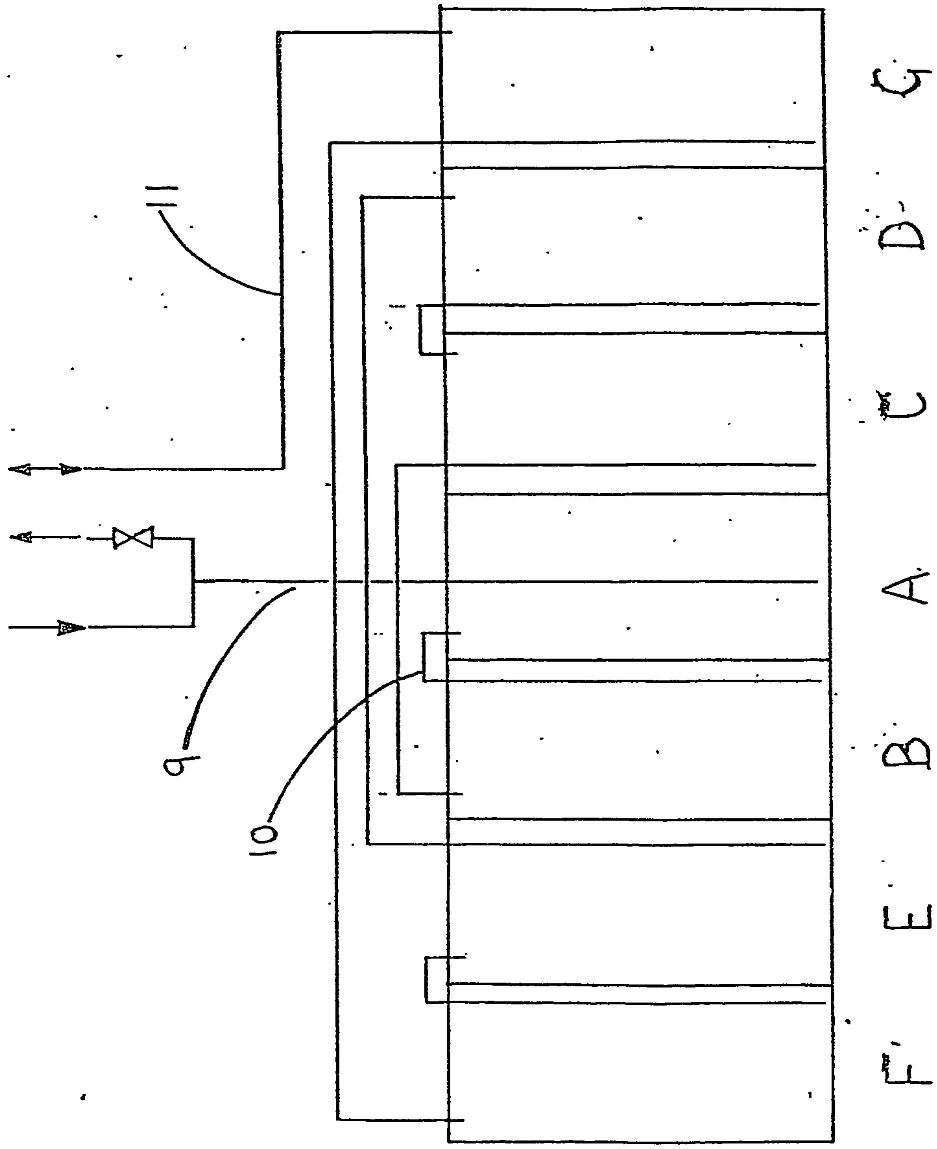


Fig 6

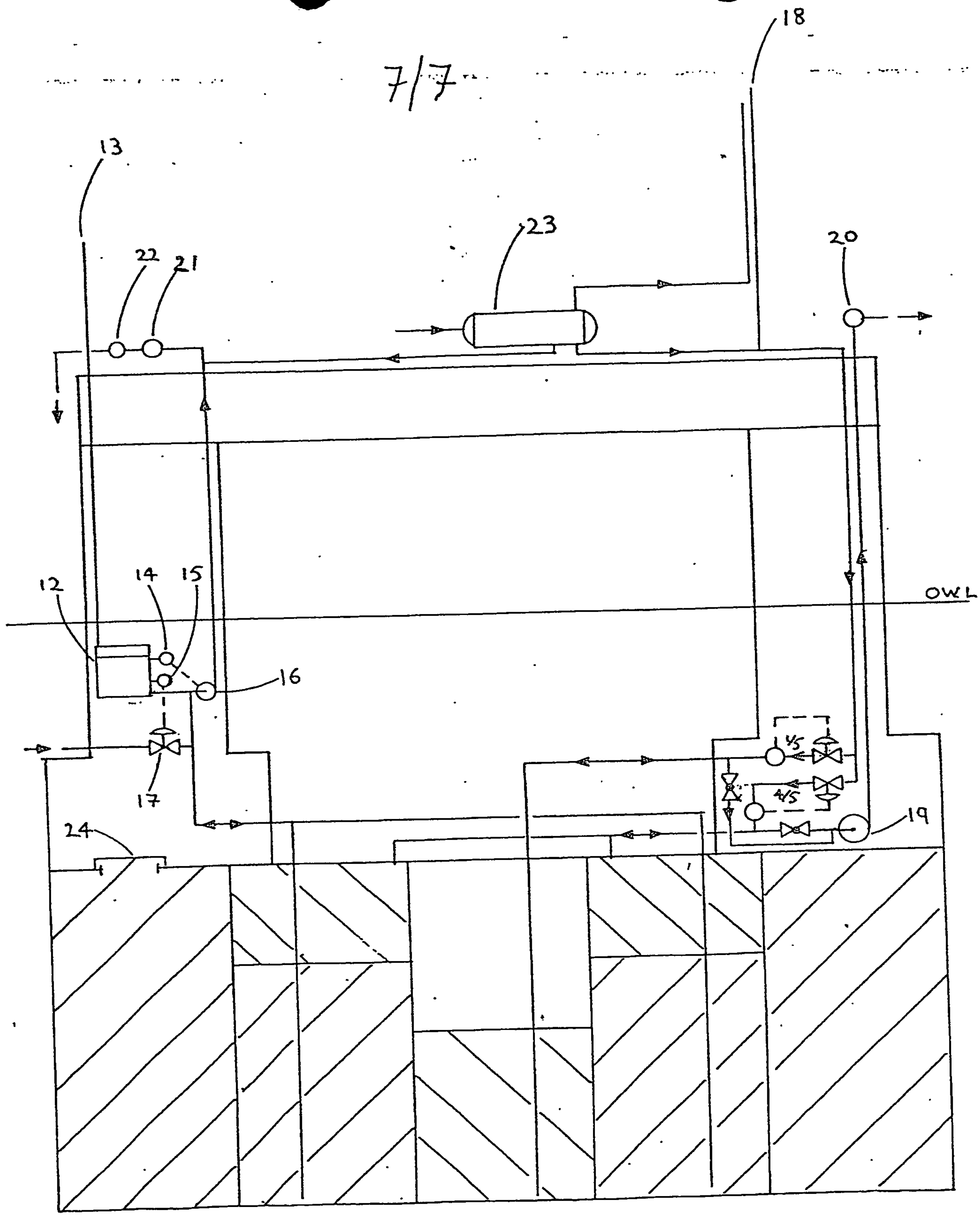


Fig 7